§30. Current Control for LHD Superconducting Coils

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The Large Helical Device (LHD) has six sets of superconducting magnets which have different characteristics and have strong coupling with each other. The control scheme of a power system for LHD coils must be based on new control theory. Because when we make controller based on the classical theory, current regulators are disturbed by others, the stability of system is lost and the coil currents may start oscillation in the worst case.

In the first step of the design, it is necessary to clear the characteristics of controlled plants which is a set of superconducting coils and normal conducting component like as support structures or plasma.

The plant equation, which is a voltage equation, is as following;

$$\begin{bmatrix} V_C \\ 0 \end{bmatrix} = s \begin{bmatrix} L_{CC} & L_{CS} \\ L_{SC} & L_{SS} \end{bmatrix} \begin{bmatrix} I_C \\ I_S \end{bmatrix} + \begin{bmatrix} R_C & 0 \\ 0 & R_S \end{bmatrix} \begin{bmatrix} I_C \\ I_S \end{bmatrix} \quad (1)$$

where V_C is terminal voltage vector, I_C and I_S are current vector flowing coils and structures, L_{CC} and L_{SS} are self inductance matrix of coils and structures, L_{CS} and L_{SC} are mutual inductance matrix, R_C and R_S are resistance matrix.

The next step is to make a control scheme. For this system, we use following scheme;

$$[V_C] = [A][I_C^* - I_C] + [B][I_C^*] \quad (2)$$

The first term in the right hand means feedback control and the second is feed forward which make high controllability without lost of stability. In the above equation, the symbol of * indicates the reference value. This control scheme is difficult and complex to install with hardware only, so we will use software control in this system.

Finally, we estimate the necessary processing performance to build previous control.

In the LHD, the twelve phase thyristor rectifiers are used to excite coils, therefore the control period becomes 720Hz. The previous control scheme requires about 800 steps for current regulation and 100 steps for condition check, so the total of steps becomes about 900 in every control period. As a result, the processor must execute 0.65 million steps in every second. This estimation is only for steady state power supplies. For the phase II operation we will build more six pulse power supplies, so necessary performance becomes twice. Also overhead caused by data exchange with other system must be considered. With these reason, we will use three processors in this control system.

Figure 1 shows a conceptual design of the control system. This figure shows two processors for poloidal and helical current control and one workstation for data acquisition and exchange. A high speed data link connects these processors. The current reference and operation commands send from upper level through network are decoded and distributed by the workstation. Also actual current values are send through this workstation. To avoid time delay and make high accuracy, inter lock signals are connected by another hard wired link.

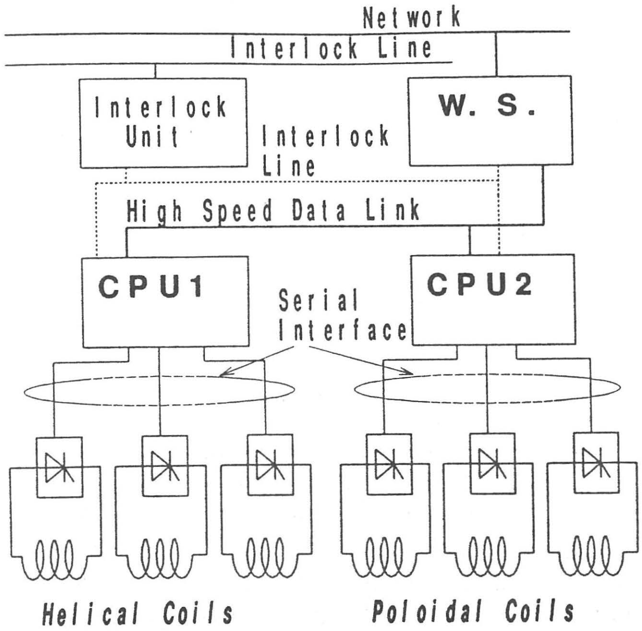

Fig. 1. Conceptual design of control system